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LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
FALL/AUTOMNE 2024

BULLETIN

SPECIAL ISSUE ON

Advances in Solids and Structures

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CONTENT

FALL/AUTOMNE 2024

COVER IMAGE - BENT STABLE STATES ALONG EIGHT ORIENTATIONS ALIGNED WITH FOUR PLANES OF SYMMETRY OF THE CONSTITUTIVE MULTISTABLE UNIT CELL / SHAHRYARI, B. ET AL. (2024). HTTPS://DOI.ORG/10.1002/ADFM.202407651

Editor's Letter

AS WE APPROACH THE HOLIDAY SEASON and many of us are traveling to visit relatives, we should reflect and be grateful to all those engineers whose dedication has enabled the development of safer and more efficient airplanes, cars, buses and trains. Many of these applications were enabled by advances in solid mechanics and material technologies. The Fall 2024 issue of the Canadian Society for Mechanical Engineering (CSME) *Bulletin* is dedicated to highlight advancements in solids and structures. It is co-edited with the CSME Technical Committees (TC) in Solid Mechanics and Material Technologies, represented by the TC chairs Dr. Akbarzadeh and Dr. Zengtao Chen, respectively. We hope that the issue will provide CSME members with an idea of what is happening in Canada in this critical area.

This issue contains feature articles from research teams led by professors Hamid Akbarzadeh, Jianyu Li and Nan Wu. Prof. Akbarzadeh's team highlights their work on triboelectric mechanical metamaterials in multifunctional energy harvesters and motion sensing devices. Prof. Li's team introduces us to the world of fracture mechanics of soft biomaterials for tissue engineering and regenerative medicine. These highlight the many new applications of solid mechanics and material technologies. Prof. Wu's team shows us that curvilinear designs for the supporting units in mechanical metamaterials offer enhanced stability, more uniform stress distribution, and improved fracture resistance. Finally, in the Q&A alumni section Behnam Ashraf gives his perspectives on the use of machine learning in material design, and the most critical requirements in advanced materials for aerospace applications.

Young researchers with new ideas are paramount to advancing the field of materials and structures. This issue highlights the work of three of them: Profs. Changhong Cao (McGill University), Osezua Ibhadode (University of Alberta) and David Mélançon (Montreal Polytechnique). Prof. Cao's lab is developing two-dimensional materials for next-generation electronics and transfer printing technologies for the high-throughput assembly of micro-LED-based display modules. Prof. Ibhadode introduces us to the world of topology optimization and highlights his contributions to open-source topology optimization software for additive manufacturing. Finally, Prof. Mélançon shares his work on highly deformable structures and his vision is to create adaptive matter capable of actuation, deformation, control, and sensing.

Please note the next CSME and CFDSC Congress which will be held on May 25-28, 2025 in École de technologie supérieure (ÉTS), Montréal (QC) (see more details inside).

The issue also contains our usual sections to keep CSME members informed, such as Prof. Ali Hosseini's CSME News, the CSME Student Affairs section, a list of future CSME awards and recent awardees, and a list of new CSME members.

In the next CSME *Bulletin* issue, guest editors Cuiying Jian and Hossein Rouhani, chair of Computational Mechanics technical committee (TC) and former chair of the Biomechanics and Biomedical Engineering TC will show us how their colleagues are developing technologies for helping us live healthier and longer lives. If you would like to suggest a topic for future issues, please let the CSME editors know your suggestions.

We hope you enjoy this issue of the CSME *Bulletin*.

Sincerely,

MARC SECANELL GALLART, PhD, MCSME, P.Eng.
Editor-in-Chief CSME *Bulletin*
Professor, Department of Mechanical Engineering
Faculty of Engineering, University of Alberta
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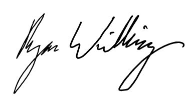

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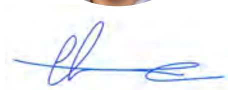

ZENGTAO CHEN, PhD, FCSME, P.Eng.
TC Chair, Materials Technology
Professor, Mechanical Engineering
University of Alberta

SUPPLIED PHOTOS

President's Message

Message du Président

Dear CSME members,

As the new president of CSME, I would like to start by thanking our past president, Dr. **Alex Czekanski**, for his incredible service. His hard work and dedication have truly made a difference for our society.

CSME is evolving to better meet the needs of our community and members. To that end, we have launched a task force focused on industrial relations to find new ways to engage with industry. I encourage all of you to reach out to your colleagues in industry and invite them to join us in our activities. Your support is vital!

The 2024 CSME Congress at the University of Toronto was a big success, with around 450 presentations and attendees. A huge thanks to our Congress Chairs, Dr. **Markus Bussman** and Dr. **Clinton Groth**, for their fantastic efforts.

Looking ahead, the next CSME Congress will be at the École de Technologie Supérieure in Montreal from May 25-28, 2025. Don't forget, the deadline for abstract and paper submissions is January 31, 2025. This year, we are excited to host a joint conference with the CFD Society of Canada and the Canadian Society of Rheology, which should bring even more valuable discussions.

We also have some updates regarding the *Transactions of CSME*. I would like to thank Dr. **Marius Paraschivoiu** for his dedicated service as the past Editor-in-Chief. His efforts have greatly enhanced the quality of our publications. We welcome our new Editors-in-Chief, Dr. **Maciej Floryan** and Dr. **Alex Czekanski**, and wish them success in their new roles.

Finally, congratulations to our Technical Award recipients: Dr. **Mohsen Akbari** (Emerging Technologies Medal), Dr. **Dominic Groulx** (Jules Stachiewicz Medal), and Dr. **Ya-Jun Pan** (Mechatronics Medal). Your achievements inspire us all.

I hope to see many of you in Montreal for the CSME 2025 Congress. Let's all get involved and make the most of our society together. CSME thrives because of you, serves you, and truly is you!

Sincerely,

Dr. **ALI AHMADI**, PhD, P.Eng., MCSME
CSME *President*
Associate Professor, Department of Mechanical Engineering
École de Technologie Supérieure

Chers membres de la SCGM,

En tant que nouveau président de la SCGM, je souhaite d'abord remercier notre président sortant, Dr. Alex Czekanski, pour son service exceptionnel. Son travail acharné et son dévouement ont fait une vraie différence pour notre société.

La SCGM évolue pour mieux répondre aux besoins de notre communauté et de nos membres. À cet égard, nous avons lancé un groupe de travail axé sur les relations industrielles afin de trouver de nouvelles façons de dialoguer et de nous engager avec l'industrie. J'encourage chacun d'entre vous à contacter vos collègues du secteur industriel et à les inviter à se joindre à nos activités. Votre soutien est essentiel !

Le Congrès 2024 de la SCGM à l'Université de Toronto a été un grand succès, avec environ 450 présentations et participants. Un grand merci à nos présidents de congrès, Dr. Markus Bussman et Dr. Clinton Groth, pour leurs efforts fantastiques.

En regardant vers l'avenir, le prochain Congrès de la SCGM se tiendra à l'École de Technologie Supérieure à Montréal du 25 au 28 mai 2025. N'oubliez pas que la date limite pour la soumission des résumés et des articles est le 31 janvier 2025. Cette année, nous sommes ravis de tenir une conférence conjointe avec la Société CFD du Canada et la Société canadienne de rhéologie, ce qui devrait apporter encore plus de discussions enrichissantes.

Nous avons également quelques mises à jour concernant les Transactions de la SCGM. Je tiens à remercier le Dr. Marius Paraschivoiu pour son service dévoué en tant qu'ancien rédacteur en chef. Ses efforts ont grandement amélioré la qualité de cette publication. Nous souhaitons la bienvenue à nos nouveaux rédacteurs en chef, Dr. Maciej Floryan et Dr. Alex Czekanski, et leur souhaitons du succès dans leurs nouvelles fonctions.

Enfin, félicitations à nos lauréats des Prix Techniques: Dr. Mohsen Akbari (Médaille pour Technologies Émergentes), Dr. Dominic Groulx (Médaille Jules Stachiewicz) et Dr. Ya-Jun Pan (Médaille pour Mécatronique). Vos réalisations nous inspirent tous.

J'espère voir beaucoup d'entre vous à Montréal pour le Congrès 2025 de la SCGM. Participons-y tous et profitons au maximum de notre société ensemble. La SCGM prospère grâce à vous, existe pour vous servir et est véritablement vous!

Cordialement,

ALI AHMADI, PhD, P.Eng., MCSME
Président, Société Canadienne de Génie Mécanique
Professeur Agrégé, Génie Mécanique
École de Technologie Supérieure

PHOTO: ÉCOLE DE TECHNOLOGIE SUPÉRIEURE

News from the *Transactions* of the Canadian Society for Mechanical Engineering (TCSME)

Transactions of the Canadian Society for Mechanical Engineering Vol. 48, No. 3, 2024 is now available online at cdnsciencepub.com/journal/tcsme.

Three Open Access manuscripts in this issue had no licensing fees for their authors through TCSME's agreements with their Canadian institutions. Read more about our Open Access Waiver for CRKN institutions at cdnsciencepub.com/journal/tcsme/publication-fees.

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CSME-CFDSC-CSR 2025

A joint conference of the CSME, CFD Society of Canada and Canadian Society of Rheology
May 25-28, 2025
École de technologie supérieure (ÉTS), Montréal (QC)

The Canadian Society for Mechanical Engineering (CSME), the Computational Fluid Dynamics Society of Canada (CFDSC), and the Canadian Society of Rheology (CSR) will hold their joint 2025 CSME-CFDSC-CSR International Congress at the École de technologie supérieure (ÉTS) in Montréal (QC) on May 25-28, 2025. This international congress presents a unique opportunity to exchange new knowledge in the many fields of mechanical engineering and to build strong networks between academia, research and industry to help accelerate innovation.

Call for Abstracts & Papers

- Both abstracts (up to 400 words) and papers (up to 6 pages) are accepted and welcome
- Papers first-authored by students are eligible for the student paper competitions
- **Submission deadline: January 31st, 2025** (see www.csmecongress.org for updates)

Additional Information and Sponsorship

- Call for special symposia and workshops
- Sponsor? – Please contact csme2025@etsmtl.ca
- For any questions, inquiries and/or proposals, please contact csme2025@etsmtl.ca

CSME Symposia	Advanced Energy Systems Advanced Manufacturing Biomechanics & Biomedical Engineering Computational Mechanics Engineering Analysis & Design Environmental Engineering Fluid Mechanics Machines & Mechanisms	Materials Technology Mechatronics, Robotics & Controls Microtechnology & Nanotechnology Smart Production Systems Solid Mechanics Sustainable Practices in Engineering Thermal Science & Engineering Transportation Systems
CFDSC Symposia	Computational Methods & Model Development Canonical Flows, Flow Physics & Turbulence	Compressible & Multiphysics Flows Applications of CFD
CSR Symposia	Theoretical & Computational Rheology, Rheometry	Applied Rheology

* For further information, visit www.csmecongress.org.

TRIBOELECTRIC MECHANICAL METAMATERIALS AS NEXT-GENERATION MULTIFUNCTIONAL ENERGY HARVESTERS

DR. HAOYU CHEN, PhD

Dr. Chen is a recent PhD graduate from Department of Bioresource Engineering at McGill University. His research focus is on mechanical metamaterial design for integrating multifunctionality in these advanced materials. His research interests include bio-inspired material design with extreme mechanical properties, all-in-one multiphysical design of architected materials, and active composites.

WEN ZUO

Zuo is a PhD student in Bioresource Engineering Department at McGill University. Her research focuses on designing multifunctional metamaterials. Her main research interests include sustainable materials for architected structures, multifunctional materials for sustainable energy production, and fiber composites for mechanical design.

DR. ABDOLHAMID AKBARZADEH, PhD

Dr. Akbarzadeh is a Canada Research Chair in Multifunctional Metamaterials, an Associate Professor in the Bioresource Engineering Department, an Associate Member in Mechanical Engineering Department, and the Director of Advanced Multifunctional and Multiphysics Metamaterials Lab (AM3L) at McGill University. His research and training program at AM3L is aligned with systematic design, multiscale multiphysical modeling, and 3D printing of (re)programmable and smart multifunctional metamaterials/structure. To date, his contributions have led to 136 published articles in well-respected journals like Advanced Materials, Advanced Functional Materials, Advanced Science, Nature Communications, ACS Nano, Nano Energy, Energy Storage Materials, Acta Materialia, and Carbon.

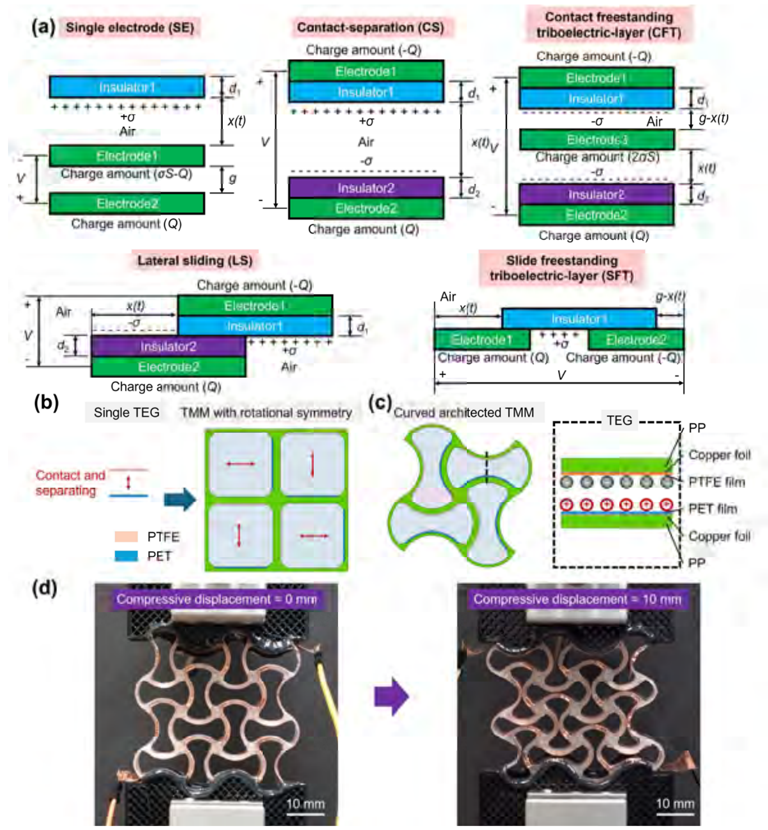

FIG. 1. INTRODUCTION OF TEG AND TMM DESIGNS: (A) DIFFERENT WORKING MODES OF TEGs. (B) DESIGN STRATEGY FROM A SINGLE CONTACT-SEPARATING TEG TO A TMM WITH ROTATIONAL SYMMETRY TEGs. (C) DESIGN OF A CURVED ARCHITECTED TMM. (D) UNIFORM DEFORMATION OF CURVED ARCHITECTED TMMs.

THE *TRIBOELECTRIC EFFECT*, ALSO KNOWN as triboelectric charging, is a type of contact electrification on certain insulators after they are separated from a material they were contacted with or rubbed against. Triboelectric generators (TEGs), which operate based on the triboelectric effect, are lightweight, portable, efficient for energy harvesting, and produce zero carbon emissions[1]. TEGs harvest electricity from mechanical energy on the basis of contact-separation (CS), lateral sliding (LS), single-electrode (SE), or contact free-standing triboelectric layer (CFT) modes (*Figure 1a*). Different modes of operation can make use of various types of mechanical deformation to change the distance between two triboelectric surfaces[2]. For example, contact-separation mode TEGs can utilize compression for energy harvesting. The distance changing can lead to the electric potential difference in the positive and negative electrodes by electrostatic induction from triboelectric surfaces. Under a unidirectional translational or rotational load, the mechanical-to-electrical energy conversion efficiency can reach 85%[2]. Capitalizing on these characteristics, TEGs are utilized in micro-power sources, self-powered sensors, and blue (salinity gradient) energy generation. TEGs have been used in the form of shape-adaptive energy harvesters to scavenge energy from human walking motions[3], origami-inspired materials to harvest ocean wave energy[4], and highly-sensitive textile arrays for epidermal physiological signal monitoring[5].

Triboelectric mechanical metamaterial design

While there are many possible applications for TEGs, given the simultaneous requirements of load bearing, mechanical energy absorbing, energy converting, and autonomous sensing/actuating properties, it is necessary to incorporate *mechanical metamaterials*, which dissipate or absorb energy along with a series of other unprecedented multifunctional properties due to their rationally-designed underlying architecture[6-8], into conventional TEGs. This integration forms a novel class of engineered materials, namely *triboelectric mechanical metamaterials* (TMMs). In the past few years, TMMs have been designed out of beam-array, honeycomb, chiral, or hierarchical architectures as substrates, together with embedded, inserted, or attached

TEGs to demonstrate their energy harvesting, sensing, vibration suppression, and load impact reduction capabilities. For instance, a novel multifunctional TMM with chiral beam architecture has been designed that can simultaneously harvest energy from the environment and attenuate vibration.

Here, a novel form of auxetic TMMs is introduced, featuring tailorable mechanical properties (i.e., stiffness, specific energy absorption, and maximum recoverable compressive strain) and efficient energy harvesting characteristics. To achieve a consistent electrical output from TEGs under multiple loading directions, rotational symmetry is introduced for designing TMMs to distribute equal numbers of TEGs in each loading axes, as shown in *Figure 1b*. Rotational symmetry however is not sufficient to realize synchronized electrical output of all TEGs in a triboelectric metamaterial. Many cellular solids feature non-uniform deformations (e.g., layer-by-layer collapse or shear band) under a uniaxial compression[10]. For TEG integration, it is critical to design topologically-optimized cellular architectures that offer a uniform deformation. An example of a proper architectural design is the auxetic curved microstructure[11]. Uniform deformation is realized by the in-plane bending of the curved cell walls when the TMM is compressed uniaxially, as shown in *Figure 1d*. With uniform deformation, both contact electrification and approaching/separating working modes of the two opposite triboelectric surfaces of TEGs are harnessed.

Electromechanical performance

Curved architected TMMs exhibit higher electrical–structural figure-of-merit (FOMes), which is a dimensionless parameter to characterize the volumetric energy harvesting efficiency and is expressed by

$$FOM_{es} = \left(\frac{2\varepsilon_0}{\sigma^2}\frac{E_m}{A\,x}\right)\Big|_{x=0-x_{max}}$$

where ε_0 = 8.854 × 10-12 F/*m* and σ (*C*/*m*^2) are the absolute permittivity of vacuum and charge density; A (*m*^2) and x (*m*) are the area and the displacement of TMM in the loading direction; *Em* (*J*) is the generated electrical energy. The overall FOM_{es} of TMMs is dependent on two factors[11]: (1) the uniformity of deformation for every TEGs and (2) the distance changing ratio $\Delta x/x_0$ of the TEGs where Δx and x_0 are the change of distance and equivalent distance between the two opposite triboelectric surfaces, respectively. The uniformity of deformation can be improved by decreasing the negative Poisson's ratio to around -1; by substituting the conventional planar shape of TEGs with curved architectures, $\Delta x/x_0$ can be greatly enhanced. As a result, the TMM design shown in *Figure 1c* with a curved architecture and the lowest Poisson's ratio demonstrate the highest FOM_{es} among all the cellular TMM counterparts[11].

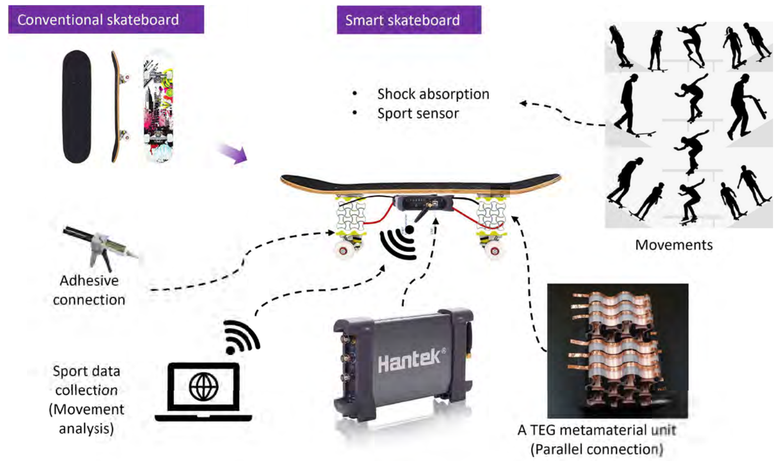

FIG 2. A DAILY-LIFE DEMONSTRATION OF APPLICATION OF TMMs FOR SPORT MOTION SENSING AND SHOCK ABSORPTION.

For TMM fabrication, a 3D printing-to-film attaching technology is proposed[11] that brings more flexibility to the triboelectric material selection to be able to include polytetrafluoroethylene (PTFE) with weak bonding performance to metals (working as electrodes)[12] in the triboelectric material system. Polymers such as PTFE are easier to obtain or lose electrons compared to the other polymers but have low surface energy and low coefficient of friction that leads to poor bonding performance. Other 3D printing technologies, like Direct Ink Writing (DIW) and Two-Photon Polymerisation (TPP) are promising to fabricate TMMs with finer microstructures to further optimize their electromechanical performance.

The electromechanical properties of TMMs have also been examined by experiments and numerical analyses[9, 11, 13]. Compression-tension cyclic loading test is usually carried out to characterize the stiffness, strength, energy dissipation, and mechanical durability of TMMs, while the open-circuit voltage and short-circuit current are measured by multimeters during the loading cycles. Finite element (FE) analysis can predict the electromechanical properties including the stress-strain curves, electrical potential change at different electrodes during deformation, and charge transfer between electrodes. Since TMMs often have a wide variety of underlying architectures designs, FE analysis of TMMs attempts to cover all representative architectures from various categories in order to draw more comprehensive results much faster than experimental studies.

Applications

As the voltage output is dependent on the compressive strain of TMMs, the potential applications of using TMMs as displacement/acceleration sensors have been investigated[11, 13-14]. Generally, TMMs exhibit tailorable stiffness, resilience, and energy absorbing capability, which facilitates their application in various loading scenarios. Here, TMMs integrated in a skateboard as an intelligent suspension system provides an example for the multifunctional applications of these mechanical metamaterials, as shown in *Figure 2*, because TMMs can absorb mechanical energy to mitigate the impacts from an uneven road and harvest the wasted mechanical energy from the impacts. Since different skateboard motions can yield distinctive combinations of compressive strains in the four wheels' suspension, the skateboard motions can be monitored by the open-circuit voltage signals from four wheels' TMM suspensions. The collected motion data can contribute to the data-driven diagnostics enabling more accurate and personalized sport training plans. It can also enable emergency response after skater's falling down, allowing for faster response and potentially life-saving interventions. In future studies, a linear relationship between the voltage output and the compressive strain of TMMs should be constructed by tailoring the TMM architectures to accurately sense the displacement. For the applications of energy harvesting from human motion and sport sensing with wearable electronics, the next generation of TMMs should be designed with unique traits such as ultra-high stretchability and flexibility.

Conclusions

In summary, TMMs possess excellent energy harvesting efficiency, remarkable mechanical performance, and extensive multifunctionalities, extending the application range of mechanical metamaterials beyond mere structural functionalities. This innovative material design technique has a great potential to impact the development of future lightweight architected triboelectrics serving as self-powered sensors[15], self-sensing materials[16], and multifunctional energy harvesters[17].

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EMERGING FRACTURE MECHANICS OF SOFT BIOMATERIALS

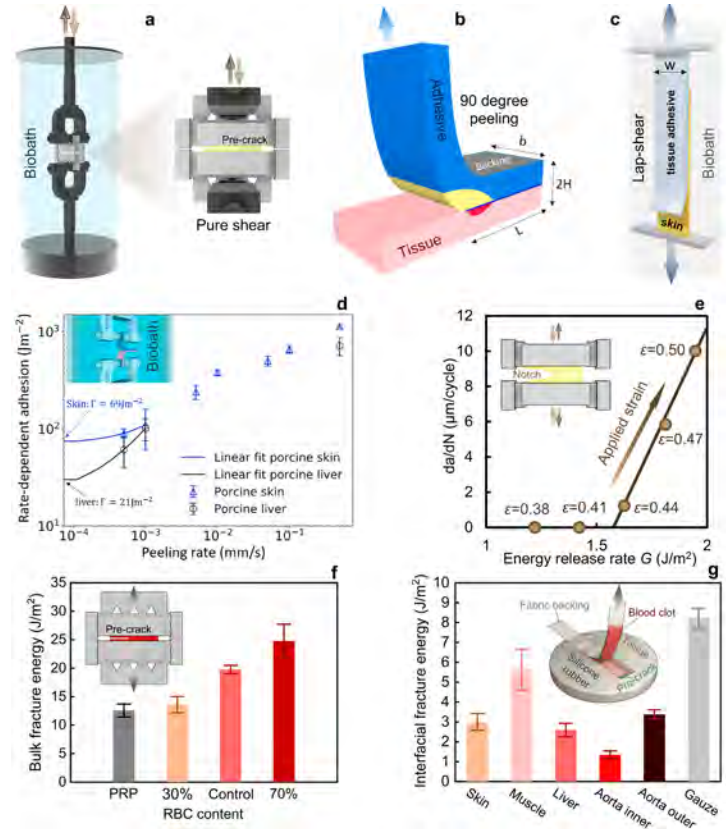

FIG. 1. SCHEMATICS OF FRACTURE TESTING METHODS FOR SOFT BIOMATERIALS: (A) PURE-SHEAR TEST[8], (B) PEELING TEST[5], AND (C) LAB-SHEAR TEST[6]. (D) RATE-DEPENDENT ADHESION ENERGY VERSUS VARIOUS PEELING RATES MEASURED USING T-PEELING TESTS[5]. (E) CRACK GROWTH RATE PER CYCLE (DA/DN) IN NOTCHED PURE-SHEAR SPECIMENS DURING STEADY STATE AS A FUNCTION OF ENERGY RELEASE RATE (G) IN UNNOTCHED SAMPLES WITH EQUIVALENT APPLIED STRAINS AS INDICATED[8]. (F) FRACTUER ENERGY VERSUS RED BLOOD CELLS (RBC) CONTENT[9]. (G) ADHESION ENERGY OF BLOOD CLOTS MEASURED ON VARIOUS SUBSTRATES USING 90° PEELING TEST[9].

ARAM BAHMANI

Bahmani is a PhD candidate co-supervised by Profs. Jianyu Li and François Barthelat in the Department of Mechanical Engineering at McGill University. He earned his MSc from the University of Waterloo in 2018 and his BSc from Iran University of Science and Technology in 2015. Aram is the recipient of the FRQNT Doctoral Scholarship and the McGill Engineering Doctoral Award.

DR. JIANYU LI, PhD

Dr. Li is an Associate Professor and Canada Research Chair in Biomaterials and Musculoskeletal Health (Tier II) in the Department of Mechanical Engineering at McGill University. He received his BEng from Zhejiang University in 2010 and completed his PhD at Harvard University in 2015, followed by postdoctoral research at the Wyss Institute at Harvard. Dr. Li focuses on developing innovative biomaterials for new technologies and therapies to enhance human health.

IMAGES COURTESY OF THE RESEARCHERS

SOFT BIOMATERIALS ARE PRESENT IN BOTH biological tissues and engineered materials for applications such as tissue engineering, regenerative medicine, drug delivery, biohybrid devices, wearable sensors, and medical implants[1-4]. These materials are characterized by their high water content, stretchy polymer networks, and often the presence of living cells. They exhibit low moduli (<1 MPa), large deformation (>100%), and coupled biological and chemo-mechanical behaviors[1-4]. This contrasts with traditional engineered materials, which have much higher moduli (>10 MPa), lower deformability (<100%), and importantly are mechanically and biologically passive. These drastic differences lead to distinct mechanical behaviors.

Fracture mechanics, a core area of solid mechanics, traditionally focuses on how cracks propagate in engineered materials such as metals and ceramics. Despite great successes in the last century, its application to soft biomaterials remains in its infancy. With the expanding use of soft biomaterials in engineering and medicine, understanding how they fracture is an emerging frontier. The importance of this is further amplified by its relevance in transdisciplinary research areas, for instance, the rupture of blood clots leading to rebleeding, and the development of bioadhesives for tissue repair and regeneration[1-4].

Fracture testing methods. Fracture could occur either within bulk materials (fracture) or along material interfaces (adhesion) under monotonic or cyclic (fatigue) loading. The fracture resistance of bulk materials is often quantified by fracture energy, typically measured using pure-shear, trouser, and single-edge notched tests[5-9] (*Fig. 1a*). This property is independent of the testing geometry and loading conditions, as seen with polyacrylamide hydrogels[5]. Interfacial fracture resistance is characterized by adhesion energy, which is typically measured using T peeling, 90-degree peeling, and lap-shear tests[5-9](*Fig. 1b,c*). Fatigue fracture, on the other hand, is assessed through cyclic loading over thousands of cycles to measure crack growth rates. This is often conducted in a Biobath chamber to simulate biological conditions[5,6,8]. These tests inform the rate of crack growth as a function of applied load cycles, from which fatigue threshold is determined—a critical value below which cracks do not propagate[5,6,8]. Recently, researchers, including our team, investigated the fracture, adhesion, and fatigue behaviors of various soft biomaterials. The following sections highlight recent progress and explore remaining opportunities.

Adhesion of hydrogel bioadhesives. Since the first report of fibrin glues[10], hydrogel-based bioadhesives have gained significant clinical use. Recent advances in achieving tough adhesion between hydrogels and biological tissues have propelled the development and application of bioadhesives. The underlying mechanical principle of integrating interfacial bonding and bulk hysteresis can amplify the adhesion energy up to 2000 $J \cdot m^{-2}$ under monotonic loading, nearly two orders of magnitude higher than that of pressure sensitive adhesives. Unfortunately, limitations remain due to the viscoelastic nature of the hydrogel matrix, which shows significant rate dependence. When peeled slowly, the viscoelastic dissipation of the bioadhesive diminishes, as well as adhesion energy, specifically, from 1000 $J \cdot m^{-2}$ at 0.5 mm/s to 80 $J \cdot m^{-2}$ at 0.5 μm/s[(5)]. Under cyclic loading, such as in body movements, bioadhesives experience interfacial fatigue fracture. In our work, lap-shear specimens formed by adhering hydrogel adhesives to porcine skin showed a significant reduction in fatigue resistance, with an adhesion fatigue threshold of 21 J/m^2, compared to 580 J/m^2 under monotonic loading (*Fig. 1d*). These results emphasize a remaining opportunity of developing fatigue-resistant bioadhesives with high fatigue threshold.

Fatigue fracture of polymeric and fibrous gels. Soft polymeric and fibrous gels, both synthetic and natural, might meet cracks and cyclic loading in applications. In the first report of fatigue fracture of hydrogels, we applied cyclic tensile loading onto hydrogels in a pure-shear configuration, and measured the fatigue threshold at 7 $J \cdot m^{-2}$ for polyacrylamide hydrogels[6]. This result aligns with the Lake-Thomas theory, correlating fatigue threshold with the energy required to rupture polymer chains between crosslinks after other dissipative processes, such as breaking physical bonds, are exhausted. We further extended this methodology to study fibrin clots; fibrous gels made from bovine platelet-poor plasma[8]. We applied 10,000 cycles onto the pure-shear specimens and determined the fatigue threshold at 1.66 $J \cdot m^{-2}$ (*Fig. 1e*). The value matched the prediction of our extended Lake-Thomas model for hierarchal fibrous gels[8]. Beyond determining the fatigue threshold, predicting the ensuing crack growth threshold remains challenging and requires further investigation under different loading conditions.

Fracture of blood clots and highly cellularized materials. Blood clots are highly cellularized materials formed at bleeding sites to serve as a mechanical barrier to halt bleeding[2,7-9]. They play an essential role in hemostasis and wound healing, and are linked with thrombotic stroke and abnormal blood clotting caused by COVID-19. Blood clots differ from conventional polymeric materials and tissue engineered scaffolds in terms of high cell density, exceeding 1 billion cells per milliliter. Because their fracture properties are critical for hemostasis, surging interests in the field are applying fracture mechanics principles to blood clots[2,7-9]. We translated the mechanical testing methods for hydrogels and elastomers to measure the fracture energy of whole blood clots, including modified lap-shear, double cantilever beam and pure shear tests[7-9] (*Fig. 1f,g*). These tests suggest that fracture energy is a reliable measure of crack resistance in clots. While fibrin has been long recognized for its mechanical significance, we found that red blood cells (RBCs) also enhance energy dissipation and fracture toughness[9] (*Fig. 1f,g*). To develop quantitative tools to model clot fracture, we showed the capacity of finite element modeling where the coupled Yeoh and Mullins model captures the constitutive behavior and the cohesive-zone model accounts for crack propagation[9]. Insights from blood clot testing provide valuable lessons for understanding the mechanics of other highly cellularized materials, such as muscle, tumors, and organoids. These complex structures require further development of experimental, theoretical, and computational tools for precise engineering.

Future perspectives. The intrinsic complexity of soft biomaterials and fracture phenomena calls for new theoretical and computational approaches. The rapid advances in artificial intelligence offer exciting opportunities to address these challenges. Model-free, data-driven techniques, such as the Koopman method, are promising for developing constitutive models for blood clots and engineered tissues[11]. These models can be further strengthened by incorporating physical laws and thermodynamic constraints, providing a robust framework for understanding soft biomaterial mechanics. Additionally, the convergence of machine learning and high-throughput testing presents opportunities to build and leverage large datasets for predictive modeling, streamlining the design of new biomaterials[11].

Engineered living and active materials, which evolve over time and respond to external stimuli, represent an exciting frontier. Self-healing materials capable of repairing cracks autonomously and mechanoresponsive materials with designer responsiveness are garnering increased attention. Concurrently, innovations in bioadhesive design—such as dynamic, reversible bonds and stimuli-responsive materials—are opening new pathways for adhesives that adapt to changing mechanical and biological conditions[12]. These novel materials not only enhance performance but also offer unprecedented systems for investigating fracture mechanics.

Looking ahead, interdisciplinary research that integrates experimental, theoretical, and computational approaches will be key to bridging the gaps in our understanding of soft biomaterial fracture. The emerging fracture mechanics of soft biomaterials fuses disciplines and promises to drive the development of new materials and structures with enhanced and predictive fracture properties.

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CURVY DESIGN IN MECHANICAL METAMATERIALS

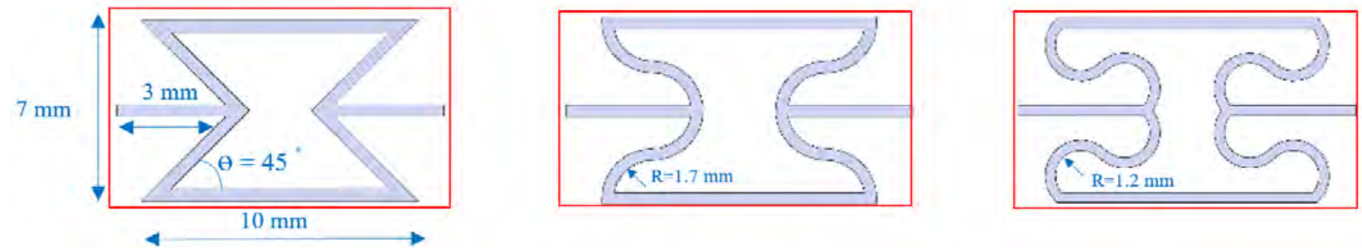

FIG. 1. CONVENTIONAL AUXETIC UNIT CELL AND MODIFIED DESIGN WITH CURVY SUPPORTS[5]; FLEXIBLE CURVY DESIGN ALLOWS EASY-TO-BEND LOCATIONS ALONG THE SUPPORTING STRUTS LEADING TO NOTICEABLE STRESS ON THEM.

RAMIN HAMZEHEI

Ramin Hamzehei is a PhD candidate at the University of Manitoba, specializing in the design of lattice structures and metamaterials for applications such as energy absorption, vibration isolation, and electricity generation. He collaborates with esteemed researchers, including Prof. Nan Wu, Prof. Muamer Kadic, Prof. Mahdi Bodaghi, and Prof. Ali Zolfagharian, to advance innovative solutions with real-world impact.

DR. NAN WU, PhD, P.Eng., MCSME

Dr. Wu is an Associate Professor at the Department of Mechanical Engineering at the University of Manitoba. He received his PhD from the University of Manitoba in 2012. His current research is on Mechanical Vibration, Smart Materials, Metamaterials, Nano-technology, and their applications to Condition Monitoring, Structural Enhancement, and Energy Harvesting. He has published over 100 journal papers in the above-mentioned fields and served on the editorial board of six international journals, including the International Journal of Mechanical Sciences *and* Composite Part B.

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MECHANICAL METAMATERIALS ARE DESIGNED to exhibit properties that are not typically found in natural world materials, driven by their internal microstructure. Adjusting the unit cell design and arrangement can achieve unique mechanical responses, such as auxetic behavior (negative Poisson's ratio), allowing the material to expand laterally when stretched and contract laterally when compressed. Due to their negative Posson's ratio, super ductility, and complex internal contact mechanisms, many mechanical metamaterials efficiently absorb and dissipate energy, making them useful in impact protection gears and damping systems[1]. Additionally, their stiffness and Poisson's ratio can be tuned by adjusting their microstructure, enabling applications from soft robotics to aerospace components[2, 3].

Due to the development of additive manufacturing technologies in the past decade, most mechanical metamaterials with complex microstructures can be efficiently fabricated. The fabrication methods/techniques include, but are not limited to, Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), and Selective Laser Melting (SLM).

Mechanical metamaterials offer groundbreaking opportunities for designing advanced materials with tailored mechanical responses, like the auxetic materials, compact energy absorbers, acoustic control materials, and smart materials with tunable stiffness. However, some challenges persist. Since many mechanical metamaterials are composed of lattice structures built from small, interconnected units, stability issues such as local and global buckling are frequently observed in traditional designs. Furthermore, significant stress concentrations often occur within their microstructures due to the irregular shapes of certain unit cells and their arrangements. This leads to fracture problems, especially under large strains, which limits some metamaterials' ability to effectively combine ductility and strength.

In this article, we will explore the application of curvilinear designs for the supporting units in mechanical metamaterials. These designs offer promising benefits, including enhanced stability, more uniform stress distribution, and improved fracture resistance. This approach may provide a viable solution for designing more functional and resilient mechanical metamaterials.

Curvy Struts in Lattice, mechanism, and their functionalities

The "S-Shape Hinge" design proposed by Khare et al.[4] is a novel feature in mechanical metamaterials aimed at improving evenness of stress distribution compared with the traditional designs like the re-entrant honeycomb structure with straight struts. The nonlinear geometry replaces straight supporting struts with smoothly curved arcs, allowing more flexible and broader elastic deformation range of the load bearing components (seen in *Fig. 1*). Such curvy design enhances performance by distributing stress more evenly along the hinge, increasing the structure's strain capacity from 3% to 30% under compression[4].

Fracture resistance functionality: Curvy strut designs play a significant role in enhancing fracture resistance[5]. Compared with the straight supports, the relatively smoother connections between struts helps in mitigating stress concentration at these critical locations that could lead to fractures under high strain, thus increasing the material's toughness. As reported in *ref. 5*, under tensile load, the curvy auxetic has elongation increased by more than 300% before fracture compared with the traditional design. Furthermore, during compression deformation, struts design with relatively larger curvature can experience earlier contacts providing additional supports to the structure with enhanced stiffness and load bearing capacity.

Energy absorption improvement: Additionally, with more evenly distributed stress through the structure, more materials under elastic and plastic deformation can contribute to energy absorption. Under tensile load, more than 200% energy absorption increment was reported in *ref. 5* by introducing the curvy design. On the other hand, under compression load, contacts between curvy elements can introduce additional friction during deformation leading to additional energy dissipation. The flexibility curves hence allow for controlled deformation and contacts of load bearing elements,generating a mechanism to absorb energy while maintaining structural integrity.

Stability enhancement (global bucking resistance): By introducing the curvy design to traditional lattices or metamaterials, the global buckling resistance can be improved through several methods. First, replacing straight struts with curvy ones in re-entrant auxetic unit cells smooths stress distributions, leading to more stable deformation. Increasing the curvature further enhances this effect. Second, adding curvy struts at the edges improves boundary stability and controls global buckling. Third, replacing high-stress areas in common auxetic cells with curvy designs helps reduce stress concentrations. Finally, in tall structures, a hybrid design combining stiff common unit cells with more flexible curvy ones can better distribute loads, enhancing overall stability.

Other characteristics/properties from unique design

Interlocking mechanisms by curvature orientation adjustment: Adjusting the orientation of individual curvy struts in the micro-structure of metamaterials allows a bio-inspired unit cell design to simulate the 'parrot beak' motion with two curved surfaces grabbing an object with obvious sliding frictional contacts, introducing tight interactions between solid parts. The design in *Ref. 6* increases structural stiffness and energy dissipation through these internal friction pairs. As seen in *Fig. 2*, during structural deformation, as the solid pair slides and locks into each other, the internal friction improves energy absorption and stabilizes the structure against buckling, and interlock behavior realizes possible bi-linear stiffness change and improves the structural stability by preventing uncontrolled slippage or collapse.

Local fracture resistance by curvy struts/cells location distribution arrangement: To avoid local fracture and re-distribute stress concentration as needed, the curvy design unit cells are strategically placed at critical fracture locations, such as notch tips, where stress concentrations are typically the highest[5], to redistribute the stress more evenly to neighbor materials reducing the likelihood of localized fracture (seen in *Fig. 3*). The curved geometry allows for smoother transitions in load-bearing areas, which in turn alleviates the sharp stress gradients that usually form around notches or other high-stress regions. This approach to distributing stress over a broader area and reducing sharp transitions at critical points improves the mechanical performance of the structure, leading to greater durability and resistance to crack initiation and propagation. Such a design is particularly beneficial in applications where structural integrity under high stress or impact is critical.

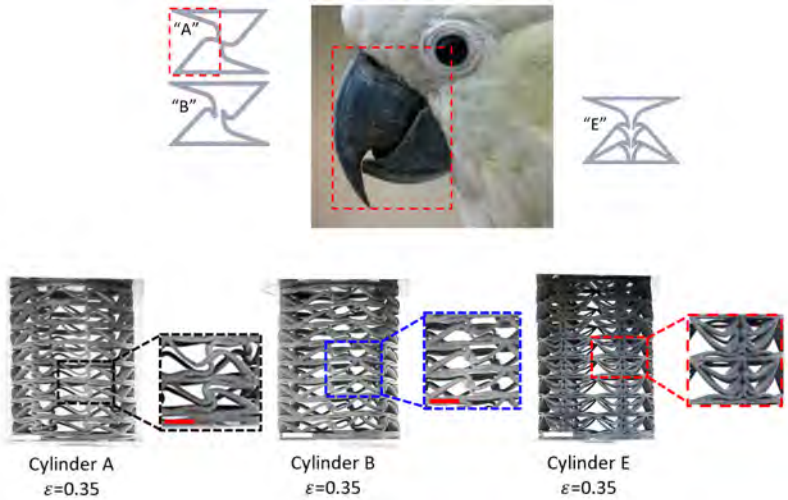

FIG. 2: PARROT DESIGN INTERLOCKING MECHANISM AT FRICTION PAIR[6]; DESIGN A IS WITH SMALL CONTACT AREA AT THE 'BEAK TIP' WITH MORE FLEXIBILITY, DESIGN B IS WITH LARGER CURVATURE AND CONTACT AREA LEADING TO MORE OBVIOUS FRICTION, DESIGN E IS WITH 'FLIP BEAKS' SHOWING THE ROTATING MOTION AT BEAK TIPS DURING DEFORMATION AND CONTACTS WITH LESS FRICTION BUT BETTER SUPPORTS.

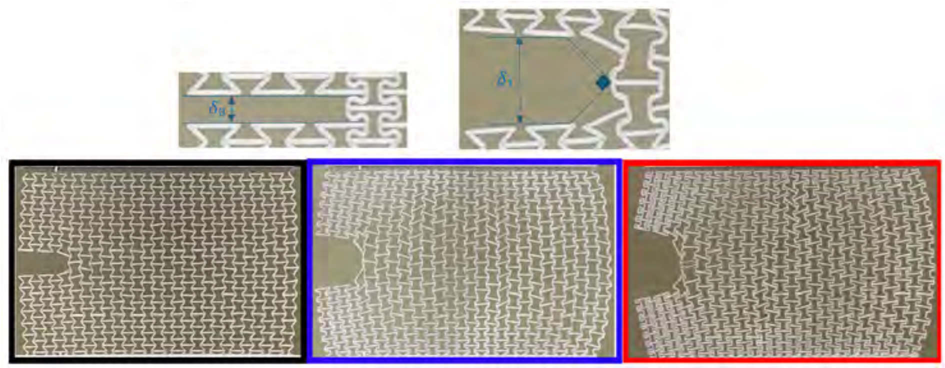

FIG. 3: LOCAL FRACTURE RESISTANCE AT NOTCH TIP DURING TENSILE DEFORMATION ALONG VERTICAL DIRECTION[5]; **δ** IS THE OPENING DISPLACEMENT OF NOTCHES, WHICH IS DETERMINED BY THE YIELD STRENGTH AND TOTAL FRACTURE TOUGHNESS OF THE LATTICE, **δ_0** IS THE INITIAL OPENING, AND **δ_1** IS THE OPENING AFTER DEFORMATION.

Future view

In summary, the curvy design not only preserves but also enhances the distinctive properties of mechanical metamaterials, such as auxetic behavior and energy absorption, while introducing new features like improved fracture resistance and greater structural stability. Further design modifications to eliminate sharp strut joints can optimize the stress distribution during deformation. And exploring the multi-material printing of curvy lattice structures could be an opportunity to further advance metamaterial designs and unlock more sophisticated functionalities. Additionally, incorporating smart materials into metamaterials to create multifunctional materials—such as self-healing and energy-harvesting systems, rather than energy-absorbing / dissipating structures—offers exciting potential for future engineering applications.

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HIGHLIGHTS

FIG. 1: MULTIMODAL MULTISTABILITY OF A SOFT ROBOTIC ARM AND ALTERNATIVE CATEGORIES OF ACHIEVABLE STABLE TRAJECTORIES.

Programmable Shape-Preserving Soft Robotics Arm via Multimodal Multistability

Mechanical metamaterials are designed to exhibit distinctive mechanical characteristics mainly due to their complex and rationally-designed geometrical structures, rather than depending only on the inherent properties of the materials they are made from. One of the crucial aspects of these types of metamaterials is multistability, which refers to their capacity to remain structurally stable in multiple configurations, enabling them to be programmed after fabrication. Inflatable multistable materials have significantly advanced the design of shape-preserving soft robotic arms, offering substantial benefits in terms of shape adaptability, energy efficiency, and safety, ensuring operational reliability even in the event of sudden power loss. However, existing strategies for constructing multistable arms often limit themselves to a single mode of multistability, commonly with rotationally symmetric designs favoring extensional stability and asymmetric designs inducing bending stability. To address these limitations, Professor Abdolhamid Akbarzadeh and his team in the Advanced Multifunctional and Multiphysics Metamaterials Lab (AM3L) in the Department of Bioresource Engineering at McGill University has recently introduced a pioneering platform termed multimodal multistability that utilizes geometrical frustration. A single cylindrical symmetric cell, designed for extensional bistability, could achieve frustrated multistable states in bending by controlling the cell with multiple degrees of freedom through an incorporated pneumatic actuator. This platform extends the spectrum of attainable stable trajectories while preserving essential attributes of arms, such as load-bearability, programmability, and reversibility of shape changes. Leveraging a pneumatic system with four degrees of freedom for pressure control, not only enables capturing previously unexplored stable configurations in mechanical metastructures but also allows for the control of their deformation modes. With applications spanning space exploration, medical instruments, and rescue missions, the multimodal multistability promises unparalleled flexibility and efficiency in the design and operation of soft robots.

The team conducted an in-depth investigation on architected cylindrical metastructures that demonstrate multiple stable states under both tension and bending by applying modal analysis to the buckling behavior of a non-planar curved beam, considered as a motif.

Through comprehensive theoretical and experimental studies on 3D printed samples, they revealed multimodal multistability within a cylindrical unit cell by precisely tuning design parameters to leverage bistability in tension and multistability in bending with stable states that can bend in any direction. Subsequently, they fabricated an inflatable, multimodal multistable soft robotics arm with a pneumatic actuator that actuates multiple degrees of freedom.

This capability allows the arm to achieve multiple, previously unexplored stable configurations, spanning a wide array of arbitrary paths. They established a direct correlation between the input pressure and the resulting deformation of the metastructure, enabling precise prediction and programming deformation sequences based on the forces and moments caused by architectural instabilities. The use of a pneumatic actuator with multiple degrees of freedom allows for precise control of input pressure, facilitating the discovery of previously unexplored stable configurations in cylindrical metastructures. Their study establishes a foundation for developing programmable, shape-preserving soft robotics arms that exhibit unique attributes such as multimodal multistability, load-bearing capability, multifunctional programmability, and reversible shape changes. — *Technical Editor, Dr. Sayyed Ali Hosseini, MCSME*

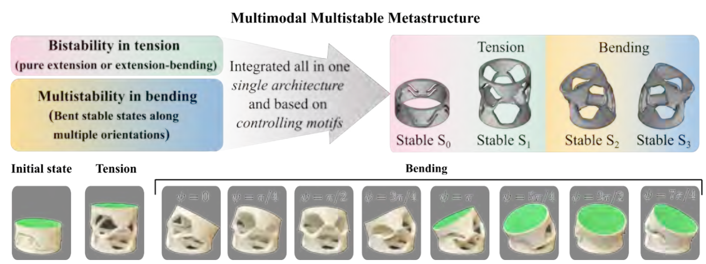

FIG. 2: CONCEPTS OF MULTIMODAL MULTISTABILITY WITHIN A SINGLE ARCHITECTURE AND BASED ON CONTROLLING MOTIFS

FIG. 3: BENT STABLE STATES ALONG EIGHT ORIENTATIONS ALIGNED WITH FOUR PLANES OF SYMMETRY OF THE CONSTITUTIVE MULTISTABLE UNIT CELL.

Reference article:
Shahryari, B., Mofatteh, H., Sargazi, A., Mirabolghasemi, A., Meger, D., & Akbarzadeh, A. (2024). Programmable Shape Preserving Soft Robotics Arm via Multimodal Multistability. *Advanced Functional Materials*, p.2407651. https://doi.org/10.1002/adfm.202407651

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Strain Driven Electrical Bandgap Tuning of Atomically Thin WSe2

2D materials are a new class of atomically thin substances known for their impressive electrical, magnetic, and mechanical properties. Such properties make them ideal for developing next-generation electronic devices. These materials boast unique features such as ultrahigh carrier mobility, field-effect switching ratios, and adjustable bandgaps, making them primary candidates for a wide range of applications, from field-effect transistors and optoelectronic devices to wearable electronics. Strain engineering provides a method to precisely adjust the lattice and electronic structures of 2D materials, allowing for achieving customizable functionalities. In semiconductors, strain engineering can improve carrier mobility and enhance the performance of silicon transistors.

Traditional materials often face challenges due to limited strain tolerance caused by defects in their 3D bulk structures. In contrast, 2D materials are highly deformable, allowing them to endure significant elastic strains without breaking. They can be subjected to substantial local strains through methods such as poking, bending, or folding. Techniques used to apply these strains include pre-straining the substrate, bending and stretching flexible substrates, altering substrate topography, inserting 2D materials into pre-etched micro-wells, and employing piezoelectric substrate actuation. These strains can potentially modify the electrical band structure of 2D materials, leading to changes in the electrical bandgap, transitions between direct and indirect bandgaps, softening or hardening of phononic modes, and shifts from semiconductors to metallic phases.

The tuning of electrical properties in 2D materials using mechanical strain has primarily been concentrated on n-type materials like molybdenum sulfide (MoS2) and graphene-tungsten sulfide (WS2). However, p-type 2D materials like bulk tungsten diselenide (WSe2) have not been extensively studied. A multinational team of researchers from Canada, USA, Japan, Australia and China led by Professor Tobin Filleter from University of Toronto, Department of Mechanical and Industrial Engineering, and Professor Chandra Veer Singh from University of Toronto, Department of Material Science and Engineering has recently investigated how controlling the mechanical strain affects the electron transport characteristics of both mono-layer and bi-layer WSe2. By integrating atomic force microscopy (AFM) nanoindentation techniques with conductive AFM, the study demonstrates the capability to precisely adjust the electronic band structure of WSe2.

The findings provide important insights into how WSe2's electronic properties change in response to mechanical strain, which is essential for developing flexible photoelectronic devices. They also discovered that when subjected to high pressure, the AFM tip/monolayer WSe2/metal substrate junction changes from Schottky to Ohmic contact, due to substantial charge transfer from the substrate to the WSe2. These insights are crucial for designing effective metal/semiconductor contacts in thin and flexible PMOS (p-type Metal–Oxide–Semiconductor) devices. *— Technical Editor, Dr. Sayyed Ali Hosseini, MCSME*

Reference article:

Islam, M.A., Nicholson, E., Barri, N., Onodera, M., Starkov, D., Serles, P., He, S., Kumral, B., Zavabeti, A., Shahsa, H. and Cui, T., Wang, G., Machida, T., Singh, C.V., Filleter, T. (2024). Strain Driven Electrical Bandgap Tuning of Atomically Thin WSe2. *Advanced Electronic Materials*, p.2400225. https://doi.org/10.1002/aelm.202400225

3D Printing of Multilayer Magnetic Miniature Soft Robots with Programmable Magnetization

Small-scale robots capable of noninvasive access to enclosed or hardly accessible areas offer significant potential as biomedical devices. Instead of embedding complex circuits and power sources, these miniaturized robots are ideally made using stimuli-responsive materials that cause them to change their shape in response to alterations in stimuli like electric or magnetic fields, temperature, light, pneumatic power, and pH. Magnetically driven soft robots are known for their quicker response times compared to devices made from shape memory polymers that rely on light or thermal stimuli. Furthermore, magnetic robots can be wirelessly controlled using a magnetic field, offering superior untethered manipulation compared to electric and pneumatic actuators. This fast, precise, and dexterous response makes magnetic actuators ideal for biomedical applications such as targeted drug delivery, cell culture, biofilm cleaning, and minimally invasive procedures.

Magnetically driven miniature soft robots respond quickly and adeptly to applied external magnetic fields. Through remote manipulation, these robots can navigate within difficult-to-reach areas, potentially for use inside the human body. Current magnetic miniature soft robots made using digital light processing are typically fabricated from flat sheets, which limits their ability to transform shapes and effective navigation. In a recent research, Professor Eric Diller and his team at the University of Toronto's Department of Mechanical and Industrial Engineering have developed a multilayer 3D printing technique that patterns magnetic nanoparticles within a UV-curable polymer matrix. Affiliated with the University of Toronto Robotic Institute as well as Institute of Biomedical Engineering, their team created various multilayer 3D structures, each under 10 mm in size, with controlled volumetric distribution across different areas, surpassing the robustness and kinematic flexibility of 2D folded shapes. By programming heterogeneous magnetization into distinctive multilayer segments of the robots, they achieved magnetic torque-induced shape changes, enabling actions such as gripping, rolling, swimming, and walking through a global actuation field. Additionally, by integrating multiple materials with unique mechanical and magnetic properties, they enhanced deformation flexibility and developed orientation-anchoring mechanisms, enabling the creation of versatile 3D multi-material actuators. *— Technical Editor, Dr. Sayyed Ali Hosseini, MCSME*

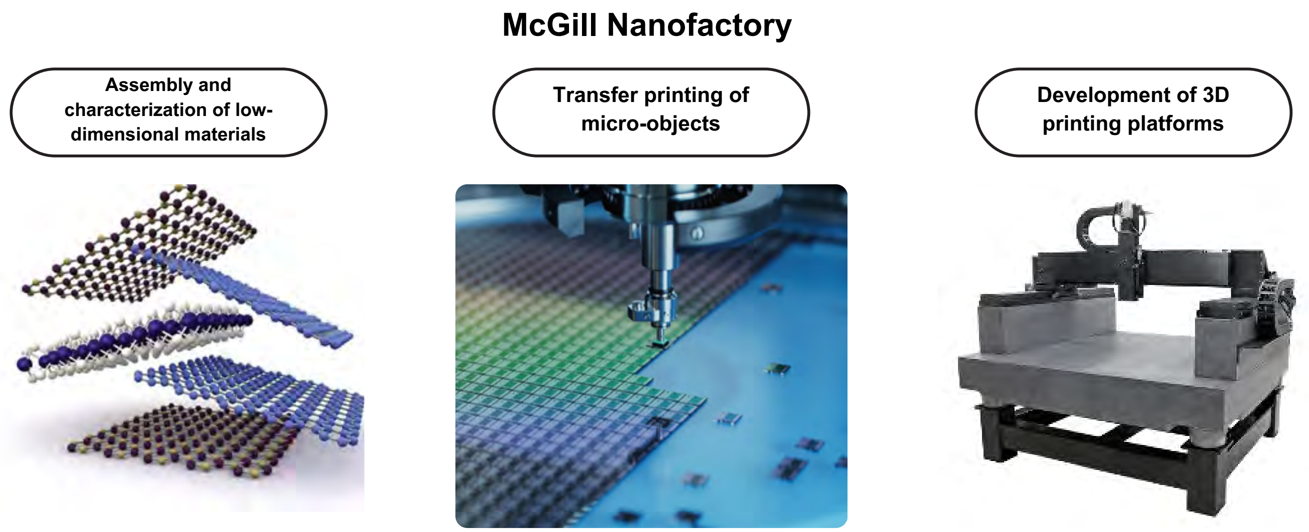
Reference article:

Li, Z., Lai, Y.P. and Diller, E., (2024). 3D printing of multilayer magnetic miniature soft robots with programmable magnetization. A*dvanced Intelligent Systems*, 6(2), p.2300052. https://doi.org/10.1002/aisy.202300052

McGill University
Dr. Changhong Cao

Putting small stuff together to do big things

FIG. 1: THREE MAJOR RESEARCH THEMES AT MCGILL NANOFACTORY LED BY DR. CAO.



Dr. Cao founded the McGill Nanofactory (www.nanofactory.lab.mcgill.ca), an innovative research center focused on providing advanced materials-based solutions to everyday challenges by developing scalable functional material systems and production processes. Positioned at the crossroads of nanotechnology, materials science, mechanics, and manufacturing, the group is building a comprehensive, closed-loop research program that spans material synthesis, characterization, device design, and production. Their expertise includes mechanical characterization at the micro- and nanoscale (sub-nanometer to micron), micro/nano transfer printing, MEMS and micro/nanomanufacturing, novel 3D printing mechanisms, and advanced characterization of energy systems.

One of the group's primary research areas is the development of cutting-edge small-scale manufacturing technologies for next-generation electronics, with a focus on two-dimensional materials (2DM). These materials, such as graphene and transition metal dichalcogenides, exhibit exceptional properties, including high electrical conductivity, flexibility, and strength, making them poised to revolutionize the electronics industry. Their applications range from faster, smaller, and more efficient transistors to sensors and memory devices. Despite their potential, scaling up the production of 2DM-based devices remains a considerable challenge, with industrial-scale manufacturing technologies still in early stages. Dr. Cao's team is exploring the mechanical properties of 2DM under various conditions—including electrical potentials, thermal gradients, and mechanical stresses—to generate insights that will inform the development of reliable, high-throughput manufacturing processes. The group has also developed custom microelectromechanical systems (MEMS) sensors and actuators for in situ SEM/TEM electro-mechanical characterizations of ultra-thin films. These findings are being leveraged to create advanced assembly technologies for 2DM-based functional devices.

In addition, the McGill Nanofactory is pioneering novel transfer printing technologies for the high-throughput assembly of micro-objects, such as micro-LED-based display modules. MicroLED displays are projected to become a multi-billion-dollar market due to their superior performance in nearly all metrics compared to traditional LEDs. However, technical bottlenecks—particularly in the mass transfer of microLEDs from their growth substrate to display backplanes—are slowing their adoption. The development of fast, accurate, reliable, and cost-effective transfer printing technologies is essential for overcoming these challenges and enabling the production of micro-LED displays at scale.

The group is also advancing experimental methodologies to evaluate the mechanical stability of energy materials, such as those used in solid-state batteries. Additionally, they are developing novel 3D printing platforms to integrate innovative synthesis techniques into additive manufacturing processes. Looking forward, the McGill Nanofactory remains committed to addressing the practical challenges in advanced materials and manufacturing. Through ongoing exploration of small-scale production processes and innovative assembly technologies, Dr. Cao's group continues to contribute to the understanding and development of functional material systems. Their work aims to support advancements in electronics, energy systems, and other fields, while maintaining a focus on translating research into solutions that can be applied in real-world contexts.

Dr. CHANGHONG CAO, PhD

Dr. Cao is an Assistant Professor and Chwang-Seto Faculty Scholar in the Department of Mechanical Engineering at McGill University. Before joining McGill, he received his PhD in mechanical engineering from the University of Toronto and worked as a postdoctoral fellow at the Massachusetts Institute of Technology. His expertise includes experimental nano-mechanics studies of advanced structures, the development of transfer printing technologies, mechano-electrochemical studies of energy materials, the development of additive manufacturing platforms, and MEMS technologies.

University of Alberta
Dr. Osezua Ibhadode

Multifunctional Design and Additive Manufacturing

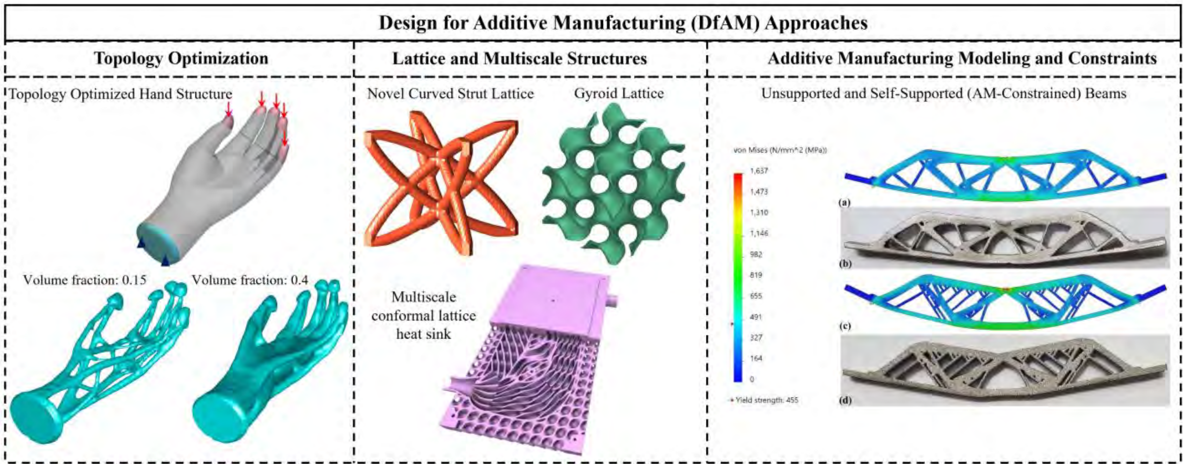


Figure 1: Three major themes in the design for additive manufacturing framework: topology optimization, lattice and multiscale structures, additive manufacturing modeling and constraints.

The global additive manufacturing (AM) industry is projected to grow at an annual rate of 24%, according to 3DHubs (www.hubs.com). This rapid growth is fueled by AM's unique layer-by-layer production method, which enables new design possibilities and allows for highly complex structures. This allows us to utilize new structural design approaches to realize design expressions previously constrained by traditional manufacturing methods. Topology optimization and lattice structure modeling are two fundamental approaches within the design for additive manufacturing (DfAM) framework[1,2] that help actualize these design expressions. While both methods have existed for decades, their practical application has only recently become possible with the advancement of AM technologies, which can now produce the intricate designs that these approaches generate. At the Multifunctional Design and Additive Manufacturing Lab, we are at the forefront of developing and employing next-generation design algorithms to create innovative structures for various industries, including aerospace, automotive, medical, energy, defense, and environmental sectors. Our research focuses on leveraging these advanced design methods to push the boundaries of what is possible in existing and emerging applications.

Dr. OSEZUA IBHADODE, PhD

Dr. Ibhadode is an assistant professor in Mechanical Engineering at the University of Alberta, Edmonton, and directs the new Multifunctional Design and Additive Manufacturing lab. His research is focused on design for additive manufacturing for multiphysics and multidisciplinary applications. He obtained his PhD in Mechanical and Mechatronics Engineering and completed a postdoctoral fellowship in the Multiscale Additive Manufacturing (MSAM) lab at the University of Waterloo.

Topology optimization is a method that determines the most efficient material distribution within a given design space to achieve an optimal objective, typically with one or more constraints. We are advancing new multiphysics and multi-objective optimization methodologies to create structurally optimal designs tailored for additive manufacturing. These approaches apply to various designs, from simple aerospace or automotive brackets to more complex components like heat exchangers and orthopedic implants. One key advantage of topology optimization is that it can incorporate manufacturing constraints into the design process, ensuring the final structure is highly functional and manufacturable. Figure 1(a) illustrates an optimized hand structure for 0.15 and 0.4 volume fractions. This optimization was done using a recently published open-source topology optimization tool, FreeTO, developed in-house that delivers optimized structures with smooth boundaries[3,4].

Recent advances in AM technologies have made lattice structures—such as porous, infill, and multiscale designs—a viable option for various applications. These structures are particularly beneficial for applications requiring lightweight designs, composite materials, bone scaffolds, impact absorbers, and more. Lattice structures are prized for their high strength-to-weight ratios in rigid applications and their increased surface areas in heat transfer applications, particularly when utilizing designs like triply periodic minimal surfaces (TPMS)[5,6,7]. In our lab, we design lattice structures using periodic and random cell distributions and innovative infill-based topology optimization methods. Figure 1 (b) highlights a novel curved strut lattice called the dual curved cubic (DCC) developed in our lab. Manufactured using a photosensitive resin, the DCC revealed significantly higher compressive yield strength than conventional geometries, recording a 70% and 86% improvement over the octet and body-centered cubic (BCC)-lattices, respectively (journal paper under preparation). Another development is a multiscale, bi-morphological conformal surface lattice-based heat sink, demonstrating a 41% reduction in thermal resistance compared to a traditional heat sink design for the same pumping power (journal paper under preparation).

It is essential to model the manufacturing process to ensure that designs are manufacturable. This allows us to predict how a structure will respond during and after printing, accounting for deformation and residual stresses. Our

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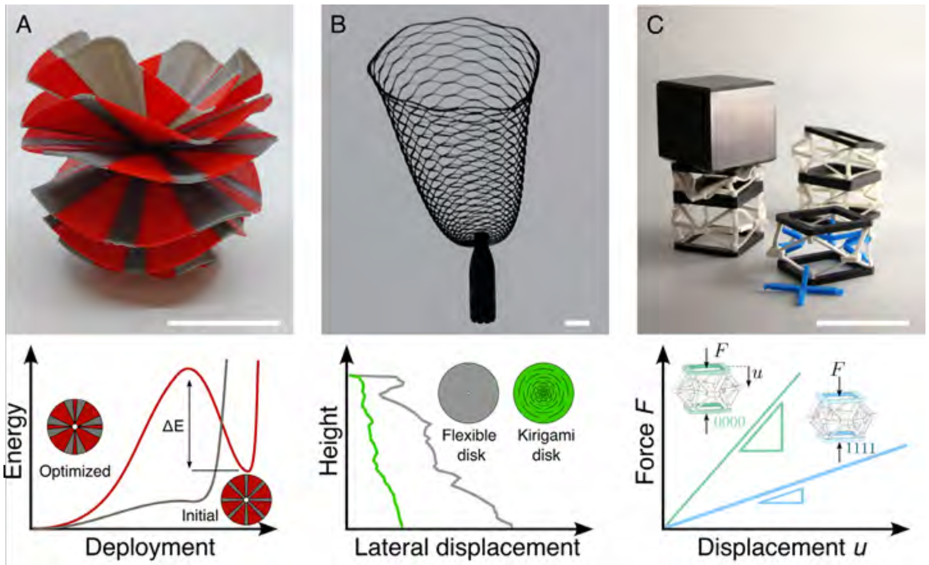
Polytechnique Montréal
Dr. David Mélançon

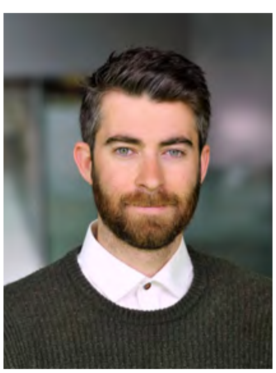
Embodying physical intelligence in soft structures through elastic instabilities



FUNCTIONALITY VIA NONLINEAR GEOMETRY IN HIGHLY DEFORMABLE STRUCTURES.
(A) OPTIMIZATION OF THE BISTABLE ENERGY LANDSCAPE OF THE WATERBOMB-BASE MOTIF.
(B) A FLEXIBLE DISK CUT WITH A KIRIGAMI PATTERN RECONFIGURES AND OPENS DURING FREE FALL TO REDUCE THE LATERAL DRIFT COMPARED TO FULLY DENSE DISK.
(C) A 3D PRINTED MECHANICAL METAMATERIAL THAT DISPLAYS STIFFNESS TUNABILITY, SHAPE MORPHING, AND MODULARITY. SCALE BARS ARE 5 CM.

IMAGES: POLYTECHNIQUE MONTRÉAL RESEARCH FIGURE (A) LUCA BOISNEAULT (B) FRÉDÉRICK GOSSELIN AND (C) YANNIS LIÉTARD.

We are transitioning from a world where material properties are primarily dictated by chemical composition to one where geometry plays a pivotal role. With advanced numerical methods and data-driven approaches, we can now tailor the micro-architecture of materials to target specific and extreme mechanical properties. Instead of avoiding instabilities, we trigger them to create transformable structures capable of morphing into distinct stable shapes. By leveraging nonlinear geometrical effects, we simplify actuation and embed intelligence into soft robots, allowing them to adapt to their environments and interact safely with humans.



Dr. DAVID MÉLANÇON, PhD
Dr. Mélançon is an assistant professor of mechanical engineering at Polytechnique Montréal. He obtained his PhD from the School of Applied Sciences and Engineering of Harvard University in 2022. He also earned a MEng from McGill University in 2017 and a BEng from Polytechnique Montreal in 2015. His current research involves the geometric design of materials, structures, and robots inspired by origami and kirigami.

In this context, the Polystable Lab at Polytechnique Montreal focuses on integrating physical intelligence into highly deformable structures. This means integrating complex and multiple functionalities in engineering systems (e.g. actuation, sensing, control) by exploiting nonlinear, geometry-driven phenomena found when inflating, folding, cutting, buckling, and shaping matter. Current research areas include multistable deployable structures inspired by origami, reconfigurable kirigami-inspired parachutes, and 3D printed mechanical metamaterials.

Origami-Inspired Bistable Systems: Bistable origami motifs exhibit two configurations in which the elastic energy in the fold lines and the facets is locally minimized. As such, they can be used to design transformable structures that lock in place after deployment. Recently, the Polystable Lab developed a robust methodology based on the Mesh Adaptive Direct Search (MADS) algorithm to optimize the bistability of origami-inspired structures, i.e., maximize the amount of energy, ΔE, required to collapse the structure (*Fig. 1A*). This technique has successfully enhanced the design of basic origami patterns, including the 4-fold waterbomb-base surfacer[1] and the Kresling cylinder[2], that can be tessellated to form functional structuresr[3]. By considering mechanical stresses during deployment, this research facilitates the transition of origami engineering from the lab to real-world applications.

Kirigami-inspired Parachutes: Parachute are expensive and delicate to manufacture, which limits their use for humanitarian airdrops or drone delivery. The art of kirigami allows programming a sheet to deform into a particular manner with a pattern of cuts, endowing it with exotic mechanical properties and behaviors. The Polystable Lab developed kirigami-inspired parachutes that deform into stably falling shapes under fluid-structure interaction (*Fig. 1B*). These parachutes are easily manufactured and deployed by laser cutting specific patterns into thin, flexible disks.Wind tunnel testing and custom numerical simulations have validated their stability during free fall, regardless of their initial release orientation, opening new avenues for practical applications in humanitarian airdrops and drone deliveries.

Mechanical Metamaterials: The Polystable Lab is also working on the design and additive manufacturing of mechanical metamaterials capable of compressive stiffness tunability, shape morphing, and post-fabrication modularity where each individual component can be reassembled to program functionality. Our 3D unit cell design is based on an assembly of bistable von Mises trusses that exhibit a switch in compressive stiffness from one stable state to the other (*Fig. 1C*). We have shown it is possible to assemble multiple units to form multifunctional sandwich panels that could be used in acoustics to build adaptive Helmotz resonators with tunable frequency absorption[4] or biomedical engineering for tunable prostheses and orthoses[5].

The lab's long-term vision is to create adaptive matter by embodying actuation, deformation, control, and sensing in the bulk materials and geometry of synthetic devices. This will enable the design of mechanical machines that adapt their shape, properties, and functionality based on external stimuli.

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Dr. BEHNAM ASHRAFI, PhD

Dr. Ashrafi is a Senior Research Officer and Team Leader for the Novel Materials & Coatings group at the Aerospace Manufacturing Technology Centre of the National Research Council Canada. He received his BSc in Mechanical Engineering from Sharif University of Technology in Tehran, Iran, in 2000, and his Master's and PhD degrees in Mechanical Engineering from McGill University in Montreal, Canada, in 2004 and 2008, respectively. Dr. Ashrafi has been an Adjunct Professor at the Department of Materials Engineering at McGill University and an Associate Fellow of Canadian Aeronautics and Space Institute (CASI). He has also been a member of the Board of Directors for the Canadian Association for Composite Structures and Materials, vice-chair for the Montreal Chapter of the American Society of Materials (ASM) and a Scientific Committee member of the International Astronautical Federation (IAF). His research primarily focuses on processing and characterizing advanced materials for aerospace, space, automotive, and defense applications. Dr. Ashrafi has co-authored four patents/patent applications, over 70 journal articles, and over 70 conference articles.

Q: Do you think the new advances in machine learning will help accelerating the rate of material discovery realized by advanced manufacturing?

Yes, advances in machine learning (ML) have the potential to significantly accelerate the rate of material discovery in tandem with advanced manufacturing. Here are several ways in which ML can contribute:

1. Predictive Modeling: ML algorithms can predict the properties and behaviors of new materials based on existing data, reducing the need for extensive experimental testing. Specifically, ML has become a powerful tool in supporting the study and understanding of complex multi-physics phenomena. These phenomena involve the interaction of multiple physical processes, such as fluid dynamics, heat transfer, electromagnetism, and structural mechanics, which can be challenging to model and simulate accurately.

2. Optimization: ML can optimize manufacturing processes by identifying the best parameters and conditions for producing materials with desired properties. With the emergence of Additive Manufacturing (AM), complex interactions between various physical processes such as heat transfer, fluid dynamics, and mechanical stresses need to be studied. ML offers several advantages for multiphysics (e.g. thermo-mechanical) topology optimization, directly aiding the advancement of single-material or multi-material AM.

In addition, ML offers advantages for data analysis and accelerated simulations, directly benefiting advanced manufacturing practices. Overall, the integration of ML into material science and advanced manufacturing holds great promise for accelerating the discovery and development of new materials, leading to innovations in various industries.

Q: What are the most critical characteristics advanced materials need to have in order to be successfully deployed in the aerospace industry?

Advanced materials used in the aerospace industry must meet several critical characteristics to ensure they can withstand the demanding conditions and requirements of aerospace applications. These characteristics include:

1. High Strength-to-Weight Ratio and Cost-Effectiveness: Materials must be strong yet lightweight to improve fuel efficiency and performance. While performance is critical, materials must also be cost-effective to produce and maintain and to be viable for widespread use in the aerospace industry.

2. Thermal Stability, Corrosion, and Fatigue Resistance: Aerospace materials must maintain their properties at extreme temperatures (e.g., engine components). They must resist corrosion from environmental factors such as moisture, salt, and chemicals, and withstand repeated stress cycles to ensure longevity and reliability. These factors, along with weight savings, are the main reasons airplane manufacturers are transitioning from metals and alloys to advanced composites.

3. Environmental Impact: Consideration of the environmental impact of materials and manufacturing processes, including use and disposal, is increasingly important in the aerospace industry.

Q: Most aircrafts are built using metal and composite materials, what role can bio-inspired ceramics play in future aerospace applications?

The main applications of advanced ceramics in aerospace include thermal protection systems, high-temperature protective coatings, and ceramic-matrix composites (CMCs) for engine components. While conventional ceramics can withstand very high temperatures, they are brittle and prone to cracking under thermal or mechanical stresses. Bio-inspired material design approaches are emerging as a method to address this issue. Compared to traditional ceramics, CMCs offer high-temperature resistance with improved toughness and resistance to thermal shock. However, CMCs face challenges such as complex manufacturing and maintenance processes, high costs, and low structural resolutions. Therefore, bio-inspiration, combined with advanced ceramics manufacturing, presents a promising alternative to replace CMCs with a more cost-effective solution that also enhances the manufacturability of ceramic-based components.

Q: What inspired you to pursue a career in mechanics and material science?

What inspires me the most is the profound impact that materials have on technology and society. It amazes me how the availability or scarcity of materials can limit many applications. Numerous fascinating concepts and innovations have been stalled due to the lack of suitable materials. Therefore, there is immense opportunity to explore this field, which also promises significant career prospects for future generations. Additionally, materials science offers an exciting intersection of disciplines such as physics, chemistry, and engineering. Working in this area ensures multidisciplinary collaborations with a diverse range of experts, providing constant learning opportunities, which is another source of inspiration for me.

The Canadian Society for Mechanical Engineering
A constituent society of the Engineering Institute of Canada

La Société Canadienne de génie mécanique
Une société constituante de l'Institut canadien des ingénieurs

NEWS COMMUNIQUÉ

Office of the President November 2024

The CSME is pleased to announce the winning recipients of its 2025 Technical Awards bestowed to members of the society for their outstanding contributions to specific disciplines of mechanical engineering. The winners are:

CSME Emerging Technologies Medal

For "exceptional research and innovation contributions to the field of biomedical engineering"

Mohsen Akbari, PhD, MCSME
Associate Professor, Mechanical Engineering, University of Victoria, Victoria, BC

CSME Jules Stachiewicz Medal

For "exceptional research and innovation contributions to the field of thermal science and engineering"

Dominic Groulx, PhD, FCSME
Professor, Dalhousie University, Halifax, NS

CSME Mechatronics Medal

For "exceptional research and innovation contributions to the field of mechatronics"

Ya-Jun Pan, PhD, FCSME
Professor, Dalhousie University, Halifax, NS

Call for Nominations – 2025 CSME Regular Awards

Nominations of CSME peers are currently solicited for regular society awards, specifically:

The **Robert W. Angus Medal** established in 1957 to honour the late Robert W. Angus who was for many years Professor of Mechanical Engineering at the University of Toronto. It may be awarded annually to a mechanical engineer for outstanding contributions to mechanical engineering practice in Canada, including industrial innovation, technology commercialization and creativity.

The **G.H. Duggan Medal** established in 1935 to honour Dr. George Herrick Duggan who was president of the EIC in 1916. It may be awarded annually to a CSME member for the best paper in the Transactions of the Canadian Society for Mechanical Engineering dealing with the use of advanced materials for structural or mechanical purposes.

The **C.N. Downing Award** established in 1993 in honour of the Founding President of the CSME, Clifford N. Downing. It may be awarded annually to a CSME member for distinguished service to CSME over many years.

The **I.W. Smith Award** established in 1977 to honour Professor I. W. Smith who devoted a lifetime to teaching mechanical engineering at the University of Toronto. It may be awarded annually to a CSME member for outstanding achievement in creative mechanical engineering within 10 years of PhD degree.

The title, **Fellow of the CSME**, may be awarded to CSME members who have attained excellence in mechanical engineering and who have contributed significantly to the progress of their profession. Nominees must have at least 10 years of professional experience and at least 5 years in uninterrupted standing as a member of the CSME, 3 years of which with active service to the CSME society..

Note that members cannot nominate themselves – worthy candidates from the diverse CSME community must be nominated by CSME Fellows.

*The deadline for submission of nominations for regular 2025 Awards is **January 31, 2025**.*

For Procedures, Terms/Criteria and the Nomination Form, visit: csme-scgm.ca/awards

CSME Emerging Technologies Medal

Dr. Mohsen Akbari

Mohsen Akbari received his PhD from Simon Fraser University and is currently an Associate Professor at the Department of Mechanical Engineering at the University of Victoria. Dr. Akbari's exceptional contributions to advanced materials, particularly the development of bioactive fibers for tissue printing and organ weaving, have led to numerous groundbreaking technologies with significant implications for tissue engineering and regenerative medicine. Dr. Akbari's commitment to knowledge translation is evident through his establishment of three companies, organization of events and symposiums, service on the boards of directors of CSME and other Canadian societies, numerous awards and recognitions, and publication of research findings in high-impact journals.

CSME Jules Stachiewicz Medal

Dr. Dominic Groulx

Dr. Dominic Groulx, Fellow of the CSME, obtained his PhD from the University of Sherbrooke and is the founder of the Lab of Applied Multiphase Thermal Engineering (LAMTE) at Dalhousie University where he has trained over 90 HQPs in the last 15 year and published over 200 journal and conference papers, book chapters and technical reports.

Dr. Groulx is a world leader in the field of solid-liquid phase change heat transfer and latent heat based thermal energy storage/thermal management, giving invited keynote lectures at the top international conferences and research centers. He is also the author of invited book chapters dealing with the design of thermal storage systems and thermal management of electronics.

Dr. Groulx was asked to be inaugural chair of the CSME Heat Transfer Technical Committee and is the current senior Canadian representative on both the Assembly for the International Heat Transfer Conference (AIHTC) and the International Center for Heat and Mass Transfer (ICHMT), representing the Canadian Heat Transfer community.

CSME Mechatronics Medal

Dr. Ya-Jun Pan

Dr. Ya-Jun Pan obtained her PhD from the National University of Singapore and is a Professor in Mechanical Engineering at Dalhousie University. She is an internationally renowned researcher in control, mechatronics and robotics and has made significant contributions in robust nonlinear control and cyber physical systems with in-depth applications to tele-robotics, cooperative autonomous systems, intelligent robotics, rehabilitations, and industrial automation.

Ya-Jun has published over 200 research articles in top journals and conferences with high citations, advancing the field of control and mechatronics and contributing to industrial practices. Her innovative work has been successfully applied to the industrial partner's commercial platforms as key technologies and made significant impact in helping their business growth.

Dr. Pan has trained over 100 graduate students and research associates. She has been recognized with fellowships in Canadian Academy of Engineering (CAE), Engineering Institute of Canada (EIC), Canadian Society for Mechanical Engineering (CSME), American Society of Mechanical Engineers (ASME), Research Excellence Award, and Humboldt Research Fellowship.

STUDENT AFFAIRS REPORT

CSME

I hope that everyone had a great summer, hopefully with some time to relax, and the fall has started off great. We've been extremely happy with student activities and engagement in both the Annual Congress at the University of Toronto and overall interest in the Student Affairs Committee. The University of Toronto CSME Local Student Chapter was very involved and engaged at the congress, leading student events and networking with other attendees which was awesome to see. I've already been having great discussions with active local chapters to initiate planning of student professional developments for the year and how to connect local chapters across the country. As always, I encourage anyone interested in becoming more involved with the CSME Student Affairs Committee to reach out to me for further discussion (dromanyk@ualberta.ca).

The Student Affairs Committee contribution to this *Bulletin* focuses on two contributions: a) Dr. Grant McSorley's write-up summarizing the National Design Competition that took place in conjunction with the Annual Congress; and, b) The University of Toronto CSME Local Student Chapter's Student Spotlight on Rafiq Omair, written by Stephanie Deng.

Current CSME Student Chapters:

- University of Toronto
- University of Alberta
- Western University

SPOTLIGHT ON

2024 CSME NATIONAL DESIGN COMPETITION WINNERS

IT WAS A PLEASURE MEETING TWO OF THE THREE WINNING TEAMS at this year's CSME Congress and presenting them with their awards. The categories for the competition were *Sustainability*, *Commercial Readiness*, and *Technical Excellence in Mechanical Engineering*, with each team receiving a certificate of achievement and a cash prize of $750. Special thanks to the University of Toronto conference committee, who provided complimentary banquet tickets for the student team members. For photos of the projects and details for the 2025 competition, visit www.csme-ndc.ca.

MEMBERS OF THE AEROFLEX TEAM RECEIVING THE TECHNICAL EXCELLENCE AWARD AT THE 2024 CSME CONGRESS BANQUET.

Sustainability Award

Team: TrashTech (Faculty of Sustainable Design Engineering, University of Prince Edward Island)
Members: SoumyaDeep Chowdhury, Ben Keizer, Luke McCarvill, Tung Nguyen
Project: Smart Household Waste Bin

To address the problem of excessive household waste production, the TrashTech team worked to develop an intelligent household waste bin analogous to a Fitbit for waste. To do so, they focused on three main subsystems: machine learning software to identify waste, a wireless-enabled smart trash bin to capture waste data, and a user interface to display the data. By the end of the project, the team successfully developed a prototype system capable of capturing the necessary data (including images and weight), categorizing waste into six distinct types with greater than 96% accuracy using a convolutional neural network, and transmitting the data to a graphical user interface over wi-fi. Through this project, the team has demonstrated how integrating advanced technology with an everyday household product can promote more sustainable habits.

MEMBERS OF THE ACKNOS PROSTHETICS TEAM RECEIVING THE TECHNICAL EXCELLENCE AWARD.

Commercial Readiness Award

Team: Acknos Prosthetics (Faculty of Applied Science and Engineering, University of Toronto)
Members: Kiran Maharaj, Amanda Reed, Sara Safadel, Oyshwarya Shamsuddin, Nili Updhyay, Muhan Yu

Project: Tactile Sensing Prosthetic Thumb

Prosthetic fingers (digits) are typically limited in their ability to provide sensory pressure feedback, which is critical for gripping objects of varying size, weight and texture. Working with an industry client, the Acknos Prosthetics team focused on developing a prosthetic thumb capable of tactile sensing by measuring and communicating the intensity and location of pressure applied across the thumb pad. The final design uses an Arduino Uno for data processing, a custom PCB for power management, a 3D printed thumb and socket with embedded pressure sensors, and a vibrotactile feedback unit. By considering material biocompatibility, user comfort, compatibility with existing prosthetics, and cost, the team succeeded in developing a product with the potential to improve the user experience and empower individuals with disabilities worldwide.

Technical Excellence in Mechanical Engineering

Team: Aeroflex (Faculty of Applied Science and Engineering, University of Toronto)
Members: Samantha Butt, Lydia Callender, Jeremy Mainella, Ana Vukojevic
Project: Robotic Legged Landing Gear

Existing search and rescue helicopters are limited to landing on terrain with a slope of less than 10 degrees, requiring dangerous maneuvers when conducting rescues in uneven or rocky territory. The Aeroflex team endeavoured to design a novel landing gear system that maintains a level fuselage by conforming to inclined and rough surfaces of up to 20 degrees while meeting the strict weight, reliability and safety requirements of the aerospace industry. Inspired by suspension systems, the team reimagined the landing gear as a flexure-based system, using an adaptable arc-sharped structure that behaves like a spring-damper system. Through detailed analysis, kinematic simulation and structural optimization, the team demonstrated that the 300M steel landing gear could successfully conform to both a 20 degree slope and a 6 inch offset, while conforming to interface, weight and federal certification requirements. They were further able to prototype the electro-mechanical design to demonstrate how using inertial sensors allowed motors to control and adapt their landing gear to complex terrain, opening the door for safer search and rescue missions in the future. — *Dr. Grant McSorley*

In the spotlight: Rafiq Omair

Third year mechanical engineering student at U of T establishes local chapter of CSME. He shares his dedication to materials science research and commitment towards student engagement.

GROWING UP SURROUNDED BY MULTIPLE engineers in his family, Rafiq Omair knew he wanted to follow in their footsteps from a very young age. At 16, he decided he wanted to pursue research and academia.

Now in his third year, Rafiq conducts research under the supervision of Professor Kevin Golovin in the Department of Mechanical & Industrial Engineering at the University of Toronto. Over the past year and a half, he has been using magnetism to create energy efficient de-icing systems. These innovations could be particularly beneficial for aircrafts, wind turbines, and other systems that are heavily affected by ice accretion.

Apart from research-related endeavours, Rafiq is also committed to mentorship and student engagement. Last year, he co-founded the U of T chapter of CSME and currently sits as co-president. His goal is to nurture a community that encourages professional development.

"We were able to help with hosting the CSME Congress at U of T in 2024 in May 2024 and we're currently working on seeing what we could offer our students following hosting our first round of events and establishing our connections with different companies here who could offer different workshops to our students and help them develop their engineering skills as well as their networking skills."

Rafiq is also chair of the Undergraduate Mechanical Engineering Club and director of external relations for U of T's Engineering Society. In these roles, Rafiq serves as a liaison between the department and student body.

"I've always enjoyed mentorship, and I've always enjoyed acting as a point of communication between certain entities when needed", he explained. "Taking on the roles that I have has allowed me to learn a lot … and I've made sure to try and push that knowledge forward as much as possible". — *Stephanie Deng*

TECHNICAL COMMITTEE REPORTS

Advanced Energy Systems

- Dr. Xili Duan from the Memorial University of Newfoundland finished his term as the Chair in May 2024.
- Dr. XiaoYu Wu from the University of Waterloo now serves as the Chair, and Dr. Leyla Amiri from Université de Sherbrooke as the Vice-Chair
- We have identified colleagues in the field to be invited to join our TC.
- We organized a webinar for the TC members on October 10, 2024. The webinar series are planned to be continued regularly.

– *Dr. XiaoYu Wu*, MCSME

Computational Mechanics

The interests of this Committee include the development of new algorithms and non-standard applications of existing algorithms. The routine use of software packages for various simulations falls outside of its interests.

The Committee has completed its website

The Committee participates in the activities of the International Association for Computatio al Mechanics. The distribution of individual memberships among its members is being completed.

The Committee organized a Symposium on Computational Mechanics as a part of the 2024 CSME Congress. This Symposium was spo sored by the Canadian National Committee for Mechanics (IUTAM).

The Committee organized, jointly with the Canadian National Committee for Mechanics, a competition for the best presentation in Computational Mechanics by a junior re searcher during the 2024 CSME Congress. The winner was Musanna Galib from the University of British Columbia. – *Dr. J.M. Floryan*, FCSME

Engineering Analysis and Design

- The TC Chair, Vice Chair and members are in place.
- Thanks to the TC Chair, Vice Chair and Dr. Alison Olechowski local Vice Chair from University of Toronto, the 2024 Symposium for the Engineering Analysis and Design TC was very successful with a large number of papers successfully presented in various sessions.
- TC Chair Aman Usmani and Vice Chair Hamid Akbarzadeh held a meeting with Hossain Rohani, Chair of the CSME TCs to discuss and plan for the TC activities such as topical Seminars, Webinars and Symposia that can be used towards meeting the PEO Professional development requirements.
- A Zoom meeting of the full TC is being planned in November

Activities Planned for 2024-25

- A CSME seminar on "An Approach to Addressing vibrations in Vertical Coolin Water Pumpss" by Aman Usmani is planned for Fall 2024.
- More webinars and seminars are being planned.

– *Dr. Aman Usmani*, FCSME

Manufacturing

Current activities:

1. Serving as an associate editor for the Transactions of the Canadian Society for Mechanical Engineering (TCSME).
2. Organizing the CSME webinar series on Manufacturing.

Future activities:

1. Organizing the Manufacturing symposium at the 2025 CSME Congress at École de Technologie Supérieure (ÉTS).
2. Continuing to serve as an associate editor for TCSME.
3. Continuing the CSME webinar series on Manufacturing, featuring both international and national invited speakers.

– *Dr. Farbod Khameneifar*, MCSME

Materials Technology

- The committee has grown its size by 1/3 with 7 new members from universities across the country, representing all regions.
- TC Chair Zengtao Chen had a meeting with Hossain Rohani, Vice President, Technical of CSME to discuss about the Material TC issues such as technical outreach, better representation of the committee by calling for more members from underrepresented regions, and the Materials symposium in the upcoming 2025 CSME conference in Montreal.
- TC Chair Zengtao Chen has been working with Dr. Hamid Akbarzadeh, Chair of Solid Mechanics TC as co-guest editors to organize one issue of CSME *Bulletin* (to appear in November 2024) to showcase the relevant activities in the communities.

Activities Planned for 2024-25

- Organizing the Materials Symposium, encourage more submissions from colleagues and students.
- Organizing annual TC committee meetings during the CSME annual conference

– *Dr. Zengtao Chen*, FCSME

Mechanics

The mission of this Committee is to popularize mechanics in Canada and provide Canadian representation to the International Union of Theoretical and Applied Mechanics (IUTAM).

The Committee organized a competition for the best presentation by a junior researcher in the areas of (i) fluid mechanics, (ii) solid mechanics, and (iii) computational mechanics during the 2024 CSME Congress. The winners were:

(i) Fluid mechanics: Muhammad Butt from the University of Toronto.

(ii) Solid Mechanics: Dr. Hang Xu from Concordia University.

(iii) Computational Mechanics: Musanna Galib from the University of British Columbia.

The Committee members (Drs Floryan, Parashivoiu, and Kim participated in the IUTAM General Assembly meetings during the 26 International Congress of Theoretical and Applied Mechanics held in Daegu, South Korea, August 25-30, 2024.

Dr. Floryan participated in the meeting of the IUTAM Congress Committee during the 26 International Congress of Theoretical and Applied Mechanics in Daegu, South Korea, August 25-30, 2024.

Dr. Floryan attended the IUTAM Symposium on Laminar-Turbulent Transition in Nagano, Japan, September 2-6, 2024. Dr. Floryan was the IUTAM delegate to this symposium.

– *Dr. J.M. Floryan*, FCSME

Solid Mechanics

- Prof. Akbarzadeh serves as CSME Solid Mechanics Symposium Chair at CSME-CFDSC-CSR 2025 International Congress in Montreal.
- Prof. Akbarzadeh and Prof. Zengtao Chen serve as a co-editor of Fall 2024 edition of CSME Bulletin on "Advanced solids and structures".
- Prof. Akbarzadeh an his team have prepared a featured article on the topic of triboelectric metamaterials for CSME Bulletin Fall 2024 edition.
- Prof. Akbarzadeh has been serving actively as an Associated Editor in Transactions of the Canadian Society for Mechanical Engineering for papers submitted around solid mechanics and manufacturing.
- Prof. Chun II Kim and Prof. Marwan Hassan serve as members of CNC-IUTAM on behalf of Solid Mechanics TC.
- Prof. Akbarzadeh has met Prof. Hossein Rouhani to discuss the mandates of the Solid Mechanics TC and come up with strategies to increase the involvement of the members.

— *Dr. Hamid Akbarzadeh,* MCSME

Dr. Abdolhamid Akbarzadeh et al., Triboelectric mechanical metamaterials (p. 8)

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Dr. Nan Wu, Curvy design in mechanical metamaterials (p. 12)

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Dr. Osezua Ibhadode, Multifunctional Design and Additive Manufacturing (p. 16)

research focuses on developing fast process models, from small-scale 2D models to large-scale 3D simulations utilizing parallel computing[8], to accurately predict these responses. By integrating process mechanisms into the topology optimization workflow, we can ensure that our designs are functional and feasible to manufacture without significant defects. In many AM technologies, a self-supporting component has structural features aligned at angles equal to or greater than 45° to the build bed, eliminating the need for extra support structures to aid printing. For instance, Figure 1(d){c,d} shows the integration of 45° strut features in a topology-optimized beam to ensure it is self-supported[9], and the unsupported beam is shown in Figure 1(d){a,b}. Under bending tests, the self-supporting beam had only a 3% decline in the maximum force compared to the unsupported beam. This highlights how manufacturing constraints can be integrated into the design process without significantly affecting the functional performance of the component.

We also develop open-source tools to make advanced design techniques accessible to a broader audience of researchers, engineers, and educators. This allows for greater diffusion of knowledge and enables valuable feedback to enhance these technologies. To explore our free and open-source software tools, visit sites.google.com/ualberta.ca/mdam/software. In the future, deep learning models (e.g., CNN, GANs) will be employed for topology optimization problems and to predict metal laser-based AM process responses (e.g., hot and cold spots based on data from photodiode or optical tomography signals) to be tied back to topology optimization.

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CALL FOR CONTRIBUTIONS TO THE NEXT CSME BULLETIN

FOCUS ON HOW CAN ENGINEERING HELP US LIVE BETTER AND LONGER?

As the Editor of the Canadian Society for Mechanical Engineering (CSME) *Bulletin*, I would like to invite you to submit any of the following items for consideration for publication in the next CSME *Bulletin* issue.

The next issue focuses on *How can engineering help us live better and longer?* and will be published in May 2025. The guest editors of the issue will be Profs. **Cuiying Jian** and **Hossein Rouhani**, chair of Computational Mechanics technical committee (TC) and former chair of the Biomechanics and Biomedical Engineering TC. We are looking for contributions in the following areas:

Featured articles: The aim of the featured articles is to give our readers an overview of a given sub-topic of the theme (Advanced Solids and Structures), the most recent advancements in the area, and finally, the most critical aspects for future research. The article should be 1,200 words (9,000 characters including spaces) long. If you are interested in submitting a featured article, please submit an Expression of Interest (EoI) by sending a 300-word abstract of the article and a 50-word biography to either Marc Secanell (secanell@ualberta.ca) or Ryan Willing (rwilling@uwo.ca) by January 15th, 2025. The most significant contributions will be invited to submit a full featured article that will be due on April 1st, 2025.

Faculty spotlight: This section highlights new faculty in the Mechanical Engineering Departments across Canada within four years of their appointment, ideally working on the topic of the issue (though not essential). The aim of this section is to introduce new faculty members to the CSME community; therefore, the article should provide a short biography, an introduction to your research (what is the topic of your research? why is the research topic important?), and a description of your laboratory including past and future work. If you are eligible and interested in submitting an article, please submit an Expression of Interest (EoI) by sending a 100-word abstract and a 50-word biography to either Marc Secanell (secanell@ualberta.ca) or Ryan Willing (rwilling@uwo.ca) by January 15th, 2025. The most significant contributions will be invited to submit a full article (500 words or 4,000 characters) that will be due on April 1st, 2025.

Short news items of interest to the ME community prior to April 15th, 2025.

Recognitions: Highlighting the achievements of ME peers (not self) prior to April 15th, 2025.

In memorials: Recognizing the passing of ME members prior to April 15th, 2025.

For examples of the above, please see previous issues at www.csme-scgm.ca/bulletin.

Thank you for your consideration. We look forward to hearing from you soon.

Marc Secanell, PhD, P.Eng.
Professor, Department of Mechanical Engineering, University of Alberta
Editor, Canadian Society for Mechanical Engineering (CSME) Bulletin
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Ryan Willing, PhD, P.Eng.
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Dr. David Mélançon, Embodying physical intelligence in soft structures through elastic instabilities (p. 17)

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The CSME Bulletin Editorial Board is looking for a Technical Editor for the magazine. The Technical Editor will be a part of the Editorial Board and will interact directly with the Editor and Associate Editor in developing the content for the magazine.

The applicants should have a bachelor's or post-graduate degree in Mechanical Engineering and be members of CSME. They will responsible for:

- Coordinating and writing the CSME ME News section;
- Reviewing two to three feature and faculty spotlight articles;
- Coordinating the acquisition of CSME History Committee contribution;
- Coordinating the acquisition of and preparing Technical Committee Reports (16 - CSME TC Reports).

For examples of the above contributions, please see previous issues at www.csme-scgm.ca/bulletin.

If you are interested in serving in this role, please contact either Prof. Secanell or Prof. Willing at secanell@ualberta.ca and rwilling@uwo.ca, respectively.

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